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(54) **FAIL-OPEN MECHANISM FOR MOTORIZED SWITCH**

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H01H 3/28	(2006.01)
H01H 3/26	(2006.01)

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CPC ***H01H 33/36*** (2013.01); ***H01H 3/28*** (2013.01); *H01H 2003/266* (2013.01)

(58) **Field of Classification Search**

CPC H01H 33/36; H01H 3/28; H01H 2003/266
See application file for complete search history.

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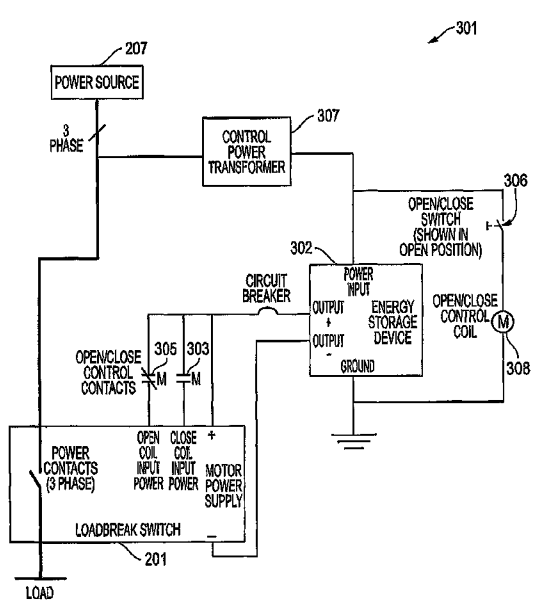
(57) **ABSTRACT**

A fail-safe motorized switching system includes: (a) a motorized loadbreak switch system, the motorized loadbreak switch system adapted for opening and closing contacts between a high voltage power source and a load; (b) an energy storage device connected to the motorized loadbreak switch system; and (c) a controller connected to the energy storage device, the controller programmed with control logic to ensure that the motorized loadbreak switch system opens the contacts between the high voltage power source and the load once the power source is removed.

10 Claims, 3 Drawing Sheets



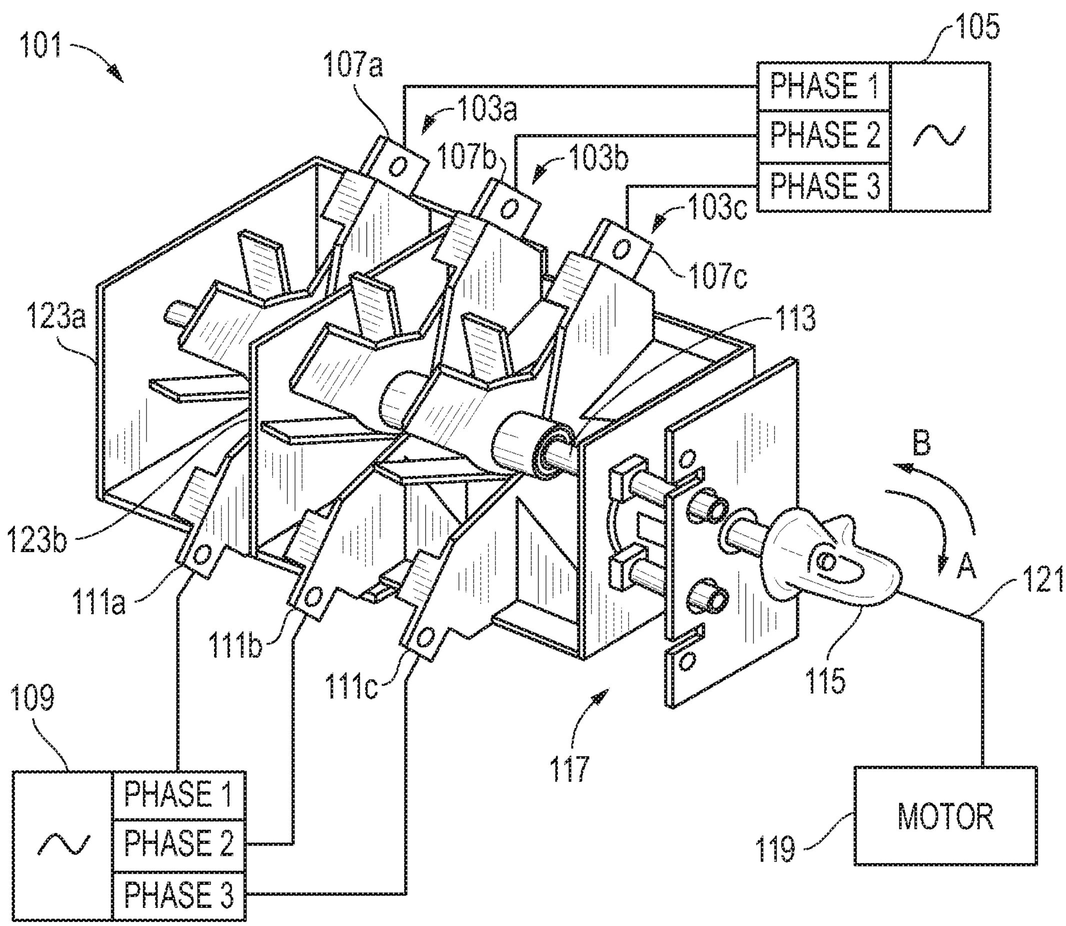


FIG. 1
(Prior Art)

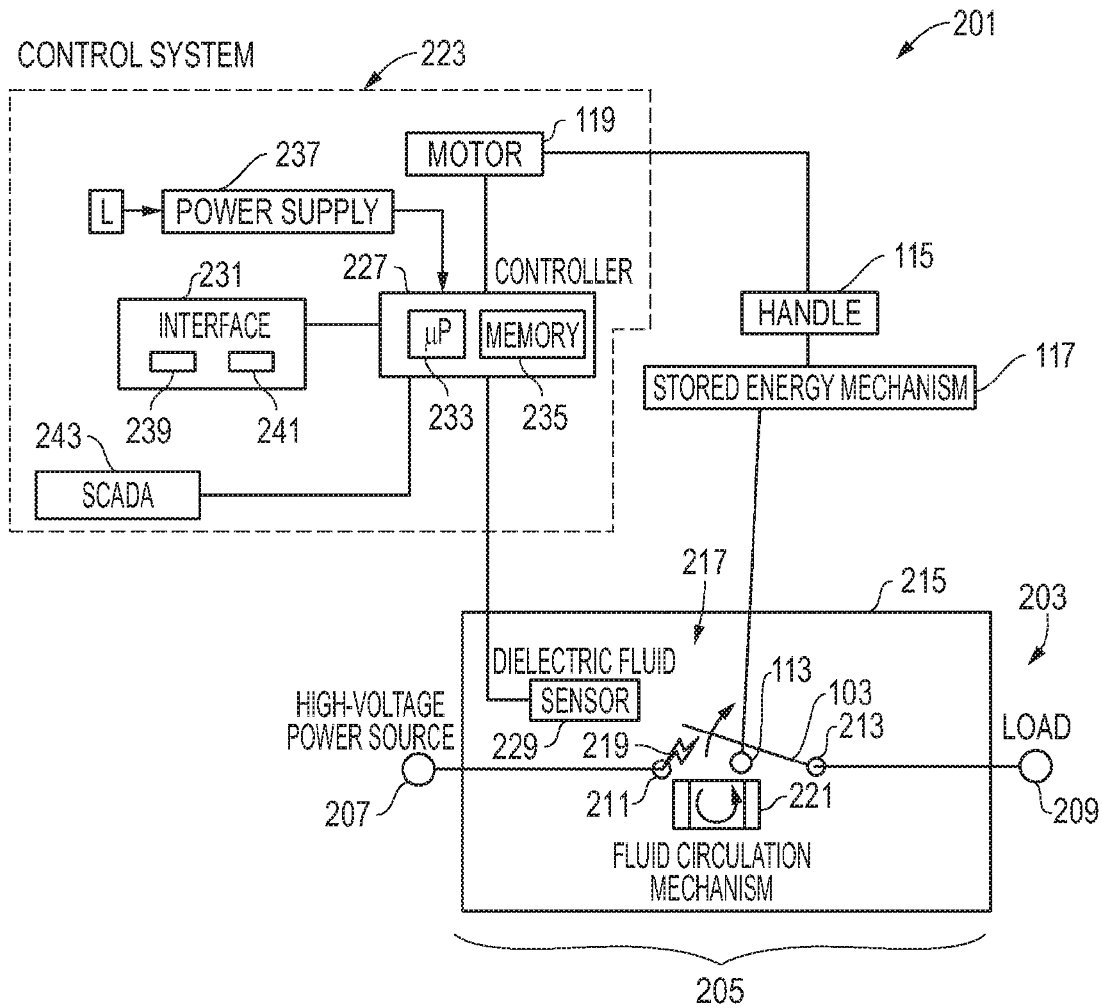


FIG. 2
(Prior Art)

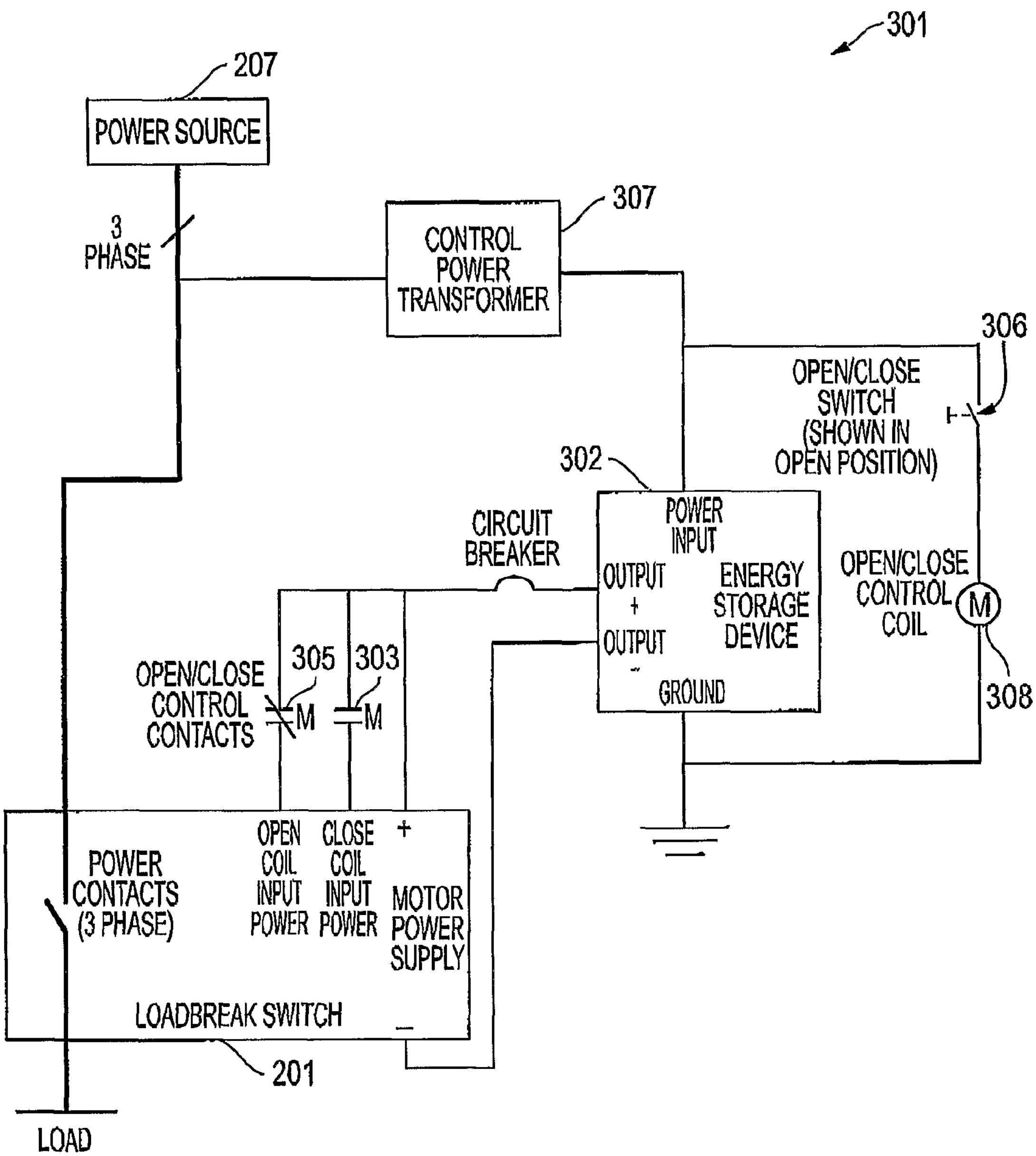

301
207
POWER SOURCE
3
PHASE
CONTROL
POWER
TRANSFORMER
307
306
OPEN/CLOSE
SWITCH
(SHOWN IN
OPEN POSITION)
302
POWER
INPUT
OUTPUT
+
OUTPUT
ENERGY
STORAGE
DEVICE
GROUND
CIRCUIT
BREAKER
OPEN/CLOSE
CONTROL
COIL
M
308
OPEN/CLOSE
CONTROL
CONTACTS
305
303
M
M
POWER
CONTACTS
(3 PHASE)
OPEN
COIL
INPUT
POWER
CLOSE
COIL
INPUT
POWER
+
MOTOR
POWER
SUPPLY
LOADBREAK SWITCH
201
LOAD

FIG. 3

FAIL-OPEN MECHANISM FOR MOTORIZED SWITCH

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to motorized switches.

2. Description of Related Art

U.S. Pat. No. 2,280,898 discloses a capacitor tripping device for circuit breakers. U.S. Pat. No. 3,064,163 discloses a capacitor trip arrangement for an electric circuit breaker. U.S. Pat. No. 3,211,958 discloses a capacitor tripping device for circuit breakers. U.S. Pat. No. 6,842,322 discloses an electronic trip device comprising a capacitor for supply of a trip coil. U.S. Pat. No. 7,432,787 discloses a motorized loadbreak switch control system and method. Each of these patents is incorporated by reference in its entirety.

High voltage switching mechanisms, such as medium voltage switchgears, currently use expensive, large-footprint contactors. Although it would be advantageous for various reasons to use motorized switches instead of contactors, unlike contactors, however, motorized switches retain their open or dosed state upon loss of power. In contactors, a magnetic coil doses the contacts once it is energized, and a spring mechanism opens the contacts once power is removed (or is lost) to the coil, thus ensuring contactors always open upon power loss.

This limitation in motorized switches renders them unusable in applications where it is desired that the switching mechanism open when power is removed. An example where such a feature is required is in some distribution-class equipment such as medium voltage switchgears or variable frequency drives where the switching device (most commonly a contactor) is used to connect the power source to the load.

In these applications, if the power supply is removed, and the switching device remains closed, once power is restored, the bad will be connected directly to the power source without any operator control, which is highly undesirable.

Although there are many designs for motorized switches that are well known in the art, considerable shortcomings remain. What is needed is a motorized switch that will automatically switch to the "open" position upon loss of power.

BRIEF SUMMARY OF THE INVENTION

In one aspect, the present invention provides a fail-safe motorized switching system comprising: (a) a motorized loadbreak switch system, the motorized loadbreak switch system adapted for opening and closing contacts between a high voltage power source and a load; (b) an energy storage device connected to the motorized loadbreak switch system; and (c) a controller connected to the energy storage device and to the motorized loadbreak switch system, the controller programmed with control logic to ensure that the motorized loadbreak switch system opens the contacts between the high voltage power source and the load once the power source is removed.

In another aspect of the invention, a method for opening and closing contacts between a high voltage power source and a load comprises the steps of: providing a motorized loadbreak switch system between the high voltage power source and the load; connecting an energy storage device to the motorized loadbreak switch system; connecting a controller to the energy storage device; and programming the controller with control logic so that the motorized loadbreak switch system opens the contacts between the high voltage power source and the load once the power source is removed.

Additional objectives, features, and advantages will be apparent in the written description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features characteristic of the invention are set forth in the appended claims. However, the invention itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings in which the left-most significant digit(s) in the reference numerals denote(s) the first figure in which the respective reference numerals appear, wherein:

FIG. **1** is a perspective view of a prior an motorized switch;

FIG. **2** is a graphical representation of a prior art control mechanism for motorized switches; and

FIG. **3** is a graphical representation of an illustrative embodiment of a fail-open system for a motorized switch of the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

FIG. **1** depicts a prior art motorized switch **101** including three rotating switches **103***a*, **103***b*, **103***c*. Each of the rotating switches **103***a*, **103***b*, and **103***c* is adapted to switch a single phase of one or more power sources, and/or one or more loads.

For example, a high voltage power source **105** might connect its first phase to stationary contact **107***a*, its second phase to stationary contact **107***b*, and its third phase to stationary contact **107***c*. A high voltage power source **109** might connect its first, second, and third phases to stationary contacts **111***a*, **111***b* and **111***c*, respectively. Thus, the rotating switch **103***a* may select alternatively between the first phase of the power sources **105**, **109** with the stationary contacts **107***a* and **111***a*, the rotating switch **103***b* may alternatively select between the second phase of the power sources **105**, **109** with the stationary contacts **107***b* and **111***b*, and the rotating switch **103***c* may alternatively select between the third phase of the power sources **105**, **109** with stationary contacts **107***c* and **111***c*.

The three-phase motorized switch **101** may be adapted to switch simultaneously each of the rotating switches **103***a*, **103***b*, **103***c*. More specifically, the rotating switches **103***a*, **103***b*, **103***c* are carried on a longitudinally extending shaft **113**, and a handle **115** extends axially from the shaft **113**. The handle **115** may be rotated, for example, in a first direction of rotation, indicated by the arrow A to charge a stored energy mechanism **117** that is also coupled to the shaft **113**. The shaft **113** may connect each of rotating switches **103***a*, **103***b*, **103***c*. For example, the shaft **113** may extend through a rotational axis of each of the rotating switches **103***a*, **103***b*, **103***c*. When released, the stored energy mechanism **117** may cause the shaft **113** to rotate the rotating switches **103***a*, **103***b*, **103***c* simultaneously, at a speed independent of the speed of the operator. Alternatively, each of rotating switches **103***a*, **103***b*, **103***c* may include a separate actuator to actuate each of rotating switches **103***a*, **103***b*, **103***c* based on rotation of shaft **113**. In either event, the three-phase power switch **101** may be used to switch simultaneously from the three phases of the first power source **105** to the three phases of the second power source **109**. Alternatively, the three-phase power switch **101** may be adapted to switch two loads between a single three-phase power source.

Once the rotating switches **103***a*, **103***b*, **103***c* are completely rotated in the first direction of arrow A, the handle **115** may be rotated in a second direction, indicated by arrow B, opposite to the direction of arrow A, to reset the stored energy mechanism **117** as described above. A motor **119** is connected to the handle **115** with a mechanical linkage **121** so that as the motor output shaft rotates a given amount in the direction of arrows A and B, so does the handle **115**. The linkage **121** may be manually disconnected from the handle **115** if needed or as desired, and the handle **115** may be manually rotated to operate the switch and/or reset the stored energy mechanism **117**. In one embodiment the handle **115** may be rotated about three hundred sixty degrees about its axis between first and second operating conditions of the switch **101**.

Baffles **123***a* and **123***b* may be provided to form an electrical barrier to suppress arcing between the separate phases, or between a phase and ground, that otherwise might cause damage to the three-phase power switch **101**. By preventing an initial phase-to-phase or phase-to-ground arc from occurring, the baffles **123***a* and **123***b* may increase safety and reliability of the three-phase power switch **101**.

FIG. **2** is a schematic diagram of an exemplary prior art high voltage motorized loadbreak switch system **201**. The system includes a motorized loadbreak switch **203**, described in detail below for illustrative purposes only to demonstrate its features.

In an exemplary embodiment, the prior art motorized loadbreak switch **203** defines an electrical path **205** between a high voltage power source **207** and a load **209**. The electrical path **205** includes a rotating switch **103** having metallic switch contacts **211** and **213**, and the rotating switch **103** is configured or adapted to open or close the electrical path **205** through the contacts **211** and **213**. The high voltage motorized loadbreak switch **203** may be used within a casing **215** that holds elements of the high voltage motorized loadbreak switch **203** immersed, for example, in a dielectric fluid **217**. In a known manner, the dielectric fluid **217** suppresses arcing **219** when the rotating switches **103***a*, **103***b*, **103***c* are opened to disconnect the bad **209** from the high voltage power source **207**. In different embodiments, the dielectric fluid **217** may include, for example, base ingredients such as mineral oils or vegetable oils, synthetic fluids such as polyolesters, SF6 gas, silicone fluids, and mixtures of the same.

The motorized high voltage loadbreak switch **203** may be located, for example, in an underground distribution installation, and/or in a poly-phase industrial installation internal to a distribution or power transformer or switchgear. Normally, current is carried through the dosed contacts **211** and **213**. When the motorized loadbreak switch **203** is opened, the

current is carried through an electrical arc that is formed as the contacts **211**, **213** open and separate. As those in the art will appreciate, the ability of the motorized loadbreak switch **203** to interrupt and extinguish the arc **219** that is formed by the opening of the contacts **211**, **213** is a function of the length the arc **219** must travel as the contacts separate, the thermodynamic and dielectric properties of the dielectric fluid **217**, the characteristics of the metal contacts **211** and **213**, the rate at which the contacts **211** and **213** are separated, the rate that the dielectric fluid **217** recovers its dielectric capability as the arc **219** cools and passes through any normal current zero in an AC circuit, and the amount and type of gas, generated as the arc **219** passes through the dielectric fluid **217**.

In view of this, the motorized loadbreak switch **203** may optionally include a fluid circulation mechanism **221** that circulates the dielectric fluid **217** around the rotating switch **103** to improve the strength of the dielectric fluid **217** by removing conductive impurities caused by arcing, such as carbonization elements and bubbles.

In an exemplary embodiment of the prior art, the rotating switch **103**, and the fluid circulation mechanism **221** is carried on a rotating shaft **113** that may be actuated by a handle **115** extending exterior to the casing **215**. The handle **115** may be turned, for example, to move the rotating switch **103** as desired, and markings may be provided on an exterior of the switch casing **215** to indicate the operating position of the rotating switch **103** when the handle **115** is in a given position. A known stored energy mechanism **117**, including, for example, spring elements, may be provided to drive or index the rotating switch **103** from one position to another to open and close the electrical path **205**. In a known manner, turning of the handle **115** charges the stored energy mechanism **117**, and once the rotating switch **103** is released via movement of the handle **115**, the stored energy mechanism **117** moves the rotating switch **103** at a proper speed to extend the arc and interact with the fluid to safely interrupt load current when the motorized loadbreak switch **203** is operated. The handle **115** may be operable, for example, to drive the rotating switch **103** in a clockwise direction or counterclockwise direction to actuate the motorized loadbreak switch **203**.

In one embodiment of the prior art, the motorized loadbreak switch **203** is, for example, a four position switch, explained further below, wherein the movement of the shaft **113** causes contact blades to shift from one position to another, and the blade movement reconfigures the connection of or isolation of power sources and/or loads by breaking or making electrical connections between contacts rotating with the shaft **113** and stationary contacts fixed to a switch block. When the handle **115** is rotated to charge the stored energy mechanism **117**, a cam system releases a locking bar so the shaft **113** is free to rotate. The shaft **113** is then driven by the energy stored in the springs, and the shaft **113** may continue to be rotated in the same direction beyond three hundred sixty degrees of rotation by actuating the handle **115**. To operate properly, the rotating switch **103**, in response to actuation of the handle **115**, must complete a switching operation and revert to an at-rest position after completion of the switching operation.

In another embodiment the prior art motorized loadbreak switch **203** may be a two position on/off switch wherein the stored energy mechanism **117** is an over-toggled-spring that controls motion of the shaft **113** over a range less than three hundred sixty degrees. In this case, the movement of the shaft **113** must be reversed to operate the switch between the on and off positions.

In either a two position or four position switch, to operate the switch correctly, the handle **115** typically must be rotated a distance beyond the release point. The movable switch contacts of the rotating switch **103** are engaged to stationary contacts mounted to switch insulating structures with sufficient force between the contacts to ensure acceptable current carrying capability. Consequently, significant input torque is required to move the handle **115** to the point of release, break the connection between the contacts, and enable the stored energy mechanism **117** to complete the remainder of the switching mechanism movement. Properly controlling input torque to the handle **115** is difficult, and operators tend to exert excessive force on the handle **115** to release the switching mechanism. Even if actuation of the handle **115** is motorized, a startup torque of the motor is not easy to control, and typically will result in some loading of the stored energy mechanism **117**. Additionally, the amount of torque necessary to release the switching mechanism may vary at different times and locations due to temperature fluctuation, current fluctuation, and other factors. Such loading, to whatever degree, of the stored energy mechanism **117** is undesirable and impairs further use of the motorized loadbreak switch **203**.

Therefore, to ensure proper operation of the motorized loadbreak switch **203**, the loading of the stored energy mechanism **117** due to actuation of the handle **115** must be removed from the stored energy mechanism **117**, allowing the mechanism **117** to return to a rest or neutral position before the motorized loadbreak switch **203** is again operated. When operated manually by a line technician with specially designed tools, the mechanism **117** is self-resetting. If used with a motorized driving system, the self-resetting mechanism **117** can easily be defeated by any residual force left on the mechanism by the motor, thereby frustrating the capability of the motorized loadbreak switch **203** to be controlled remotely.

To alleviate these and other concerns, a control system **223** is provided. As shown in FIG. **2**, the control system **223** may include a motor **119**, a controller **227** communicating with the motor **119**, one or more sensors or transducers **229** communicating with the controller **227**, and a control interface **231**.

The motor **119** is responsive to the controller **227** and is mechanically linked to the switch handle **115** to turn the handle **115** to a position wherein the rotating switch **103** is released and the stored energy mechanism **117** may complete the movement of the rotating switch **103** to, for example, a fully opened or fully closed position. As one example, the motor **119** may be a known electric motor, and in a further embodiment the motor **119** may be a stepper motor that rotates an output shaft incrementally to predetermined positions, and the position of the motor output shaft may be precisely positionable. A variety of AC and DC electric motors may be used to power the handle **115** to a release position wherein the stored energy mechanism **117** may complete the movement of the rotating switch **103**.

The controller **227** may be, for example, a microcomputer or other processor **233** coupled to the motor **119** and the control interface **231**. A memory **235** is also coupled to the controller **227** and stores instructions, calibration constants, and other information as required to satisfactorily operate the motorized loadbreak switch **203** as explained below. The memory **235** may be, for example, a random access memory (RAM). In alternative embodiments, other forms of memory could be used in conjunction with RAM memory, including, but not limited to, flash memory (FLASH), programmable read only memory (PROM), and electronically erasable programmable read only memory (EEPROM).

Power to the control system **223** is supplied to the controller **227** by a power supply **237** configured or adapted to be coupled to a power line L. Analog to digital and digital to analog converters may be coupled to the controller **227** as needed to implement controller inputs from the sensor **229** and to implement executable instructions to generate controller outputs to the motor **119**

The control interface **231** may be provided, either at the site of the motorized loadbreak switch **203** or in a remote location, and the interface **231** may include one or more control selectors **239** such as buttons, knobs, keypads, touchpads, and equivalents thereof that may be used by an operator to energize the motor **119** and open or close the motorized loadbreak switch **203**. The interface may also include one or more indicators **241**, such as light emitting diodes (LEDs), lamps, a liquid crystal display (LCD), and equivalents thereof that may convey operating and status information to the operator. The control interface **231** is coupled to the controller **227** to display appropriate messages and/or indicators to the operator of the motorized loadbreak switch **203** and confirm, for example, user inputs and operating conditions of the motorized loadbreak switch **203**.

In response to user manipulation of the control interface **231**, the controller **227** monitors operational factors of the motorized loadbreak switch **203** with one or more sensors or transducers **229**, and the controller **227**, through the motor **119**, actuates the switch handle **115**. The controller **227** may further be coupled to a remote operating control system **243**, such as known Supervisory Control and Data Acquisition (SCADA) system. Using the remote operating control system **243**, the motorized loadbreak switch **203** may be remotely monitored and controlled.

Referring now to FIG. **3**, an energy storage device **302**, such as an uninterruptable power supply or battery, is continually charged by a control power transformer **307** fed by the power source **207**. To open or close the high voltage loadbreak switch system **201**, using control logic, power from the energy storage device **302** is directed to either an "open coil" control contact **303** or a "close coil" control contact **305** associated with the loadbreak switch system **201**. The energy storage device **302** also provides power to the motor **119** inside the loadbreak switch system **201**.

During normal operation (i.e. while power source **207** is supplying power), the user can control the opening and closing of the loadbreak switch **201** by using the open/close switch **306**. If the open/close switch **306** is moved to the close position, the open/close control coil **308** becomes energized, and the normally closed control contact **305** and the normally open control contact **303** change state and are opened and closed, respectively. The output of the energy storage device **302** is thus directed to the close coil input power terminal of the loadbreak switch **201**, thus closing the loadbreak switch **201**. If the user opens the open/close switch **306**, the open/close control coil **308** becomes deenergized, and the normally closed control contact **305** and the normally open control contact **303** change their state to their normal state and are closed and opened, respectively, and the output of the energy storage device **302** is thus directed to the open coil input power terminal of the loadbreak switch **201**, thus opening loadbreak switch **201**.

In case of loss of power supply from power source **207** and, subsequently, control power transformer **307**, the open/close control coil **308** becomes deenergized regardless of the position of the open/close switch **306** ensuring the normally closed control contact **305** and the normally open control contact **303** are back to their normal state, and thus directing power from the energy storage device **302** to the open coil input power terminal of loadbreak switch **201**.

In other words, the control logic is designed such that upon loss of power, the output of energy storage device **302** is directed to the open coil input power terminal of loadbreak switch **201**, and energy storage device **302** is designed such that it stores sufficient energy to energize the open coil of loadbreak switch **201** in the absence of power source **207**.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope of the invention. Accordingly, the protection sought herein is as set forth in the claims below. Although the present invention is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications.

What is claimed is:

1. A fail-safe motorized switching system, comprising:

a motorized loadbreak switch system, the motorized loadbreak switch system adapted for opening and closing a contact between a high voltage power source and a load;

an energy storage device connected to the motorized loadbreak switch system; and

control circuitry comprising a switch and a coil, the switch having an open position and a closed position that causes a supply of energy from the energy storage device to the motorized loadbreak switch system for closing the contact, the coil having an energized state corresponding to the closed position of the switch and a de-energized state corresponding to either the open position of the switch or a loss of power supply from the power source, wherein when the coil is in a de-energized state the motorized loadbreak switch system opens the contact between the power source and the load.

2. The system of claim **1**, wherein the motorized loadbreak switch system further comprises a motorized loadbreak switch and a control system for controlling the operation of the motorized loadbreak switch.

3. The system of claim **2**, wherein the control system further comprises a control interface comprising at least one input selector and at least one indicator, the control interface configured to: accept, via the at least one input selector, operator input for controlling the motorized loadbreak switch, and display information regarding the motorized loadbreak switch via the at least one indicator.

4. The system of claim **3**, wherein the motorized loadbreak switch further comprises a motorized switch, the motorized switch comprising:

a plurality of rotating switches on a longitudinally extending shaft;

a handle extending axially from the shaft;

a motor coupled to the shaft, and

a stored energy mechanism coupled to the shaft.

5. The system of claim **4**, wherein the handle is adapted to be manually rotated to operate the motorized switch and to reset the stored energy mechanism.

6. A method for opening and closing contacts between a high voltage power source and a load, comprising the steps of:

providing a motorized loadbreak switch system between the high voltage power source and the load;

connecting an energy storage device to the motorized loadbreak switch system; and

connecting circuitry to the motorized loadbreak switch system and to the energy storage device wherein the circuitry comprises a switch and a coil, the switch having an open position and a closed position that causes a supply of energy from the energy storage device to the motorized loadbreak switch system for closing the contact between the high voltage power source and the load, the coil having an energized state corresponding to the closed position of the switch and a de-energized state corresponding to either an absence of power from the high voltage power source or the open position of the switch, wherein when the coil is in a de-energized state the motorized loadbreak switch system opens the contact.

7. The method of claim **6**, wherein the motorized loadbreak switch system comprises a motorized loadbreak switch and a control system for controlling the operation of the motorized loadbreak switch.

8. The method of claim **7**, wherein the control system further comprises a control interface comprising at least one input selector and at least one indicator, the control interface configured to: accept, via the at least one input selector, operator input for controlling the motorized loadbreak switch, and display information regarding the motorized loadbreak switch via the at least one indicator.

9. The method of claim **8**, wherein the motorized loadbreak switch further comprises a motorized switch, the motorized switch comprising:

a plurality of rotating switches on a longitudinally extending shaft;

a handle extending axially from the shaft;

a motor coupled to the shaft, and

a stored energy mechanism coupled to the shaft.

10. The method of claim **9**, wherein the handle is adapted to be manually rotated to operate the motorized switch and to reset the stored energy mechanism.

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